On January 23, 2014, the San Francisco Bay Conservation and Development Commission (BCDC) convened a Sand Resources Science Panel for the following purpose:

> *To assist the Commission, staff, stakeholders and the public in understanding the complex nature of coarse grain sediment transport, the biological community present and the connection to the immediate and greater food web. Further, the panel will assist Commission staff in better understanding the potential for impacts from sand mining in Central and Suisun Bay, and the likelihood of those impacts on the physical environment and the associated biological community.*

The panel was engaged in four Discussion periods addressing:

1. Sediment Transport;
2. Sand Replenishment;
3. Biological Connections;
4. Habitat Disturbance and Recovery.

Workshop audio was recorded by a consultant to Hanson Marine Aggregates and transcribed into a full written transcript (~85 pages). The abridged transcript presented here is produced from that full transcript, with additional reference to the audio transcript where necessary, as follows:

- Original phrasing and language was preserved where appropriate for an abridged document, however, rephrasing was often performed for brevity and clarity.
- Where rephrasing was necessary, the original intention and purpose was preserved.
- **Bold** indicates call-out of panelist statements for Commission staff attention.

The panel Discussions were preceded by two formal presentations by Bill Butler and Patrick Barnard. Those presentations are not summarized here.

Panel Moderator: Jessie Lacy, USGS
Panelists:

Patrick Barnard, Coastal Geologist, USGS
Aaron Carlisle, Post-doctoral scholar, Hopkins Marine Station
Scott Fenical, Contributor to CEQA analysis (transport modeling), Coast & Harbor Engineering
Jay Johnson, Contributor to CEQA analysis (benthic survey), Applied & Marine Science

James Lindholm, Marine Ecologist, CSUMB

Francis Parchaso, Marine Biologist, USGS

Mark Stacey, Civil and Environmental Engineering, UC Berkeley

Discussion Session 1

9:00 a.m. – 10:50 a.m.

Topic: Sediment Transport

- Patrick Barnard: There is no good or conclusive data on beach erosion north of the Golden Gate. The coast north of the Golden Gate is a mostly rocky coast with pocket beaches. South of the Golden Gate, the coast is mostly sandy and is easier to study.
- Patrick Barnard: It is unknown if the Russian River is a sand source to the San Francisco Bay Area outer coast.
- Patrick Barnard: Net vertical loss at the mouth of the Golden Gate is about 77 cm over 50 years (~1 cm per year).
- Patrick Barnard: Suspended fine/medium sand, and a sediment pulse in general (induced by a high flow event), takes about 8-12 days to travel from Suisun Bay to Central Bay (Li Erikson). Michael McWilliams' modeling corroborated this, and included bedload in that transport rate estimate.
- Patrick Barnard: 80 million cubic meters of sediment (that used to feed into the Delta and the Bay) is now withheld by dams. The previous transport mechanisms are now eroding the Delta.
- Patrick Barnard: The transport system is becoming supply-regulated; the currents in San Francisco Bay could move sand, but the sand supply is cut off by the flood control system in the Delta.
- Patrick Barnard: What type and how much sediment is transported through the Golden Gate isn't well understood.
- Patrick Barnard: The mouth has been losing about two million cubic meters of material per year over the last 50 years or so.
- Patrick Barnard: [G. K. Gilbert] inferred that about 30 million cubic meters of Gold Rush legacy material made it all the way out of the Golden Gate.
- Patrick Barnard: Potential transport of sediment through the Golden Gate is on the order of about a million cubic meters per year.
- Patrick Barnard: Three to four million cubic meters of sediments per year is taken out-of-system by dredging (in total, that has summed to 50-80 million cubic meters of dredged material).
- Patrick Barnard: Supply is 1.5 million cubic meters per year from the Delta (estimate is that 10% of this is sand, but whether that percentage is accurate today is in question).
- Mark Stacey: It's important for us to think about rates, not just volumes (i.e., rate of extraction versus rate of transportation, not volume versus volume). The key question is **what's the relative magnitude of the flux disruption versus the ongoing flux.**

- Patrick Barnard: Ocean Beach erosion is basically shifting to the north, and the collapse of the ebb-tide delta is leading to accretion along northern Ocean Beach and Baker Beach, and subsequently at Crissy Field.
- Patrick Barnard: The collapse of the delta has completely changed the wave field, especially for southern Ocean Beach and beyond.
- Patrick Barnard: At Southern Ocean Beach in particular, there are other aggravating erosive factors – not just the collapse of the ebb-tidal bar. Among them are the fact that the shoreline was built out during the great highway construction in the 1920s (unnatural placement and armoring). Secondly, there is an outfall pipe with a rock crown that is meant to be buried offshore. There's scour of one to two meters around that rock crown, causing a canyon effect and actually driving the hydrodynamics in such a way to build a rip current in the lead of this scoured outfall pipe. The erosion is most acute in that area.
- Scott Fenical: The vast majority of what has been taken out of the mining lease areas was still missing when analyzed. So, **there wasn't anything coming back to fill in the mining areas significantly, only a small proportion of what had been taken out.**
- Scott Fenical: **Mining holes are maintaining, they're affecting local transport and local hydrodynamics, but there's not a sediment deficit being created anywhere except for the degree of replenishment.**
- Mark Stacey: The nature of the bed load transport is according to the dune structures, and those structures take a certain amount of time to develop and slowly progress. **A disruption of the dune structure changes the transport trends.** So even in the absence of a volumetric change, there is potential to disrupt those fluxes. Quantifying that disruption may be impossible.
- Mark Stacey: One idea is to **look at the side scan data and whether there are differences in the size or structure of the bed forms between active mining regions and not, see if there's any direct evidence of disruption to that bed load transport locally.**
- Patrick Barnard: With multiple successive single-beam surveys, can see that the bedforms are very actively moving, migrating in the order of, in some cases, five or ten meters a year.
- Patrick Barnard: You can't really get a sense for the local disruption based on that one multi-beam survey, but maybe in the next one -- that is the focus [of the next multibeam survey of the area].
- Patrick Barnard: Over the past 15 years, commensurate with the ebb tidal delta shrink, **there has been ~5-10% regional reduction in mean grain size along the ebb-tidal delta**

and a bit to the south as well. This speaks to the regional reduction of supply (and is perhaps related to) the tidal prism reduction over the last century.

- Jay Johnson: The Applied Marine Sciences study that was provided says **that sites known to have been mined in the previous 36 months had significantly less medium-grain sand.**
- Patrick Barnard: We know the directions of movement and the spatial variation with a fair degree of certainty.
- Mark Stacey: The quantitative fluxes of the natural processes remains a key uncertainty. The way I'm kind of thinking of this is we've got a tightly driven conveyor belt that's gradually moving sand through the different embayments out to the ocean. Freshwater flows are providing the supply at the head of this conveyor belt. Then somewhere along the way, the mining is taking things off of the conveyor belt. **Quantifying the rate of the conveyor belt movement is really important to understand the implications of how much we're taking off and how much is coming on.**
- Patrick Barnard: Based on bedform studies, we definitely show that **there's a net flux seaward.** Quantifying it beyond that is extremely difficult.
- Mark Stacey: The plumes of fines that are being released in conjunction with these events probably have a clearing time of two to 20 hours. With the types of tidal transport we're talking about, plumes can reach quite a spatial extent in two to 20 hours. That will have immediate impacts on Delta ecology and fish that are sensitive to turbidity. **But it also then eventually manifests itself again in the benthic grain size distribution.**
- Patrick Barnard: Flood control and climate change have capped the peaks in the hydrographs. There's not a lot of optimism in terms of having the flood events that can transport huge amounts of sediment into the bay. Related to that is the sustainability of the bay margin and tidal marshes and a lot of the restoration activities.
- Patrick Barnard: Currently, I think Noah Knowles (?) and Dave Schoellhamer did some work and showed that currently there's about 200,000 cubic meters of sediments applied to tidal marshes. To keep up with sea level rise we need about 20 million cubic meters of sediment per year.
- Patrick Barnard: At Point Knox Shoals, there are suggestions from the modeling of the bed forms that there is active transport toward that area, which is dominated by very coarse material.
- Patrick Barnard: We may be seeing an armoring effect at Point Knox Shoals if the aggregate mining is rejecting all the very, very coarse material.
- Scott Fenical: The conveyor belt metaphor (proposed above) may be applicable to certain areas and not so much to others. **In Suisun Bay, the mining areas line up with**

the conveyor belt and are therefore in-line with the replenishment mechanism. In Central Bay in particular, it's just a complex pattern of transport, so it's not exactly the same kind of concept.

- Mark Stacey: Replenishment will reflect local responses as opposed to the net Bay transport. I think it's an important distinction.
- Patrick Barnard: **The average replenishment of sand mining in Central Bay is about 15 percent, but there's a lot of spatial variability that speaks to the variability in transport directions and fluxes throughout the Central Bay area.**

Discussion Session 2

11:10 a.m. – 12:00 p.m.

Topic: Sand Replenishment

- Scott Fenical: We came to the conclusion that most of what was mined was not filling back in.
- Scott Fenical: There's a pretty close correlation between the loss of material in Central Bay and the volume mined.
- Scott Fenical: **We see a clear signal that the lease areas weren't replenishing at nearly the rate of extraction.**
- Patrick Barnard: It's likely that the current rates of extraction can't be maintained.
- Patrick Barnard: **The bed levels aren't going to be able to be maintained at current rates of extraction.**
- Patrick Barnard: In the last decade that only 5-15% of material that was removed was actually naturally replenished.
- Patrick Barnard: New research suggests that adjacent to inlets, estuaries are likely to be a net import of sediment under higher sea level rise. So we'd see higher rates of erosion along the outer coast (Ocean Beach) and more input of sediment into San Francisco Bay over the course of the 21st century.
- Patrick Barnard: Over last decade we've seen 4-5 meters of shoreline accretion at North Ocean Beach, a lot of accretion at Baker Beach, and a lot of accretion at Crissy Field. This sediment is likely re-circulating under Presidio Shoals and then to some extent being jetted back out.
- Mark Stacey: Mining divots are relatively small-scale schemes to the Bay. Salt effects in Central Bay would be minimal. There may be some trapping in the holes initially, but that's going to get flushed out pretty readily.
- Mark Stacey: If the Suisun Bay mining leads to a widening of the channel, there could be impact on salt fluxes but it's unclear what volume of mining would be required.
- Aaron Carlisle: **Any disruption of the sea floor provides refugia for a variety of animals. So, one can predict early that there will be different colonizers of those divots. And to the extent that the divots persist, those communities might persist.**
- Patrick Barnard: Massive flood events have minor impact on the circulation in the fairly well-mixed Central Bay.
- Patrick Barnard: In Suisun Bay, flood events affect sediment movement and sediment supply. In Central Bay, flood events affect sediment supply (more than sediment movement).
- Mark Stacey: At the Golden Gate, about 80% of the tidal asymmetry is actually set by the horizontal (lateral) variation of the tides. That's why you have corridors of fluxes in

and corridors of fluxes out. Instead of a bottom and top exchange, it's a side-to-side exchange with a jet down the core and a return flow on the edges, and I think that's very consistent with the residual transport derived from the bed forms.

- Bob Battalio (Audience member was requested input from panel): **Sand moves from the western part of the Presidio Shoal on shore to the Crissy Fields Beach into the city, and the coast guard Pier and NOAA offices and then migrates eastward.** The process is a little hard to follow because transport is in pulses when there's large ocean swell that mobilizes the sediment off the western edge of the Presidio Shoal. We think that sand ultimately comes from Ocean Beach.
- Patrick Barnard: I think it's **an interesting concept to track down the borrow pit locations and look at the bathymetric change or recovery.**
- Mark Stacey: If Borrow pits are disconnected from the rest of the transport (not replenished and not affecting flux), they might primarily impact ecology. Deep holes might trap salt and induce persistent stratification - **there are some risks to creating features that are not coupled to the rest of the dynamics**.
- Scott Fenical: In Suisun, the limited data that we had did show some deepening in the control areas, following big hydrologic events.
- Mark Stacey: **Looking at [Schoellhamer's] estimates of Delta loading on the order of 2-2.5 million tons per year, that number seems to be pretty close to the 2 million cubic yards per year that is being proposed for the mining take. We're getting down close to the point where we're taking out what's coming in.**
- (General conversation): **It would be useful to dial in a box model of the coarse-grain, fine-grain, and total sediment system of San Francisco Bay.**
- Mark Stacey: **Caution not to fall into the trap of thinking that prior to some particular date the ebb-tidal delta was in a static equilibrium.** It's evolving in a much broader system than just the bay.

Discussion Session 3

1:00 p.m. – 2:25 p.m.

Topic: Biological Connections

- Jay Johnson: The Delta faunal community is a *Corbula*/*Corbicula* community
- Jay Johnson: In the Central Bay the community structure is pretty minimal (very few species, and only a few species are dominant). Dominance was by arthropods. There's very little carbon, there's very little food. So the animals that would be feeding on carbon aren't going to be present.
- Jay Johnson: **Very few studies have looked at the community at coarse sediment sites.** All the data that SFEI has been collecting for almost 20 years is all looking at contaminants and soft bottom sediments. In fact, in the regional monitoring program, where most of the data for San Francisco Bay comes from, sites that have a predominant sand composition are rejected.
- Jay Johnson: **A few years ago NOAA was doing some ROV surveys in Central Bay, and I have not seen what those produced.**
- Jay Johnson: **The Applied Marine Sciences study hypothesis is that the high energy of the Central Bay controls the community structure. The mining itself isn't the primary physical factor affecting community composition.**
- James Lindholm: **Habitat value of the bay floor to fish is: (1) that it provides habitat for their prey, and (2) the habitat created by prey species, which can provide refugia (e.g. amphipods form tube mats, and these tubes provide refuge habitat).**
- James Lindholm: **There is a coupling between fishes, the epifauna, and the infauna, and this coupling will vary spatially and temporally. The timing of the mining with lifestage events is important to this coupling.**
- Aaron Carlisle: Impacts to fish will not be equal across species. Benthic species will likely be impacted, while demersal fish will be less impacted. **We don't really have the data to know exactly what fish are using these habitats.**
- James Lindholm: **Demersal fishes select for habitats based on the period of the sand wave. So mechanically changing the sea floor could impact animals with those kind of associations.**
- James Lindholm: **Flatfishes, which we know occur in San Francisco Bay, behave differently in different flow regimes over different sand waves at different heights.** So they have different behaviors that respond to the sand wave period and the flow regimes. Any mechanical change in those bed forms could conceivably alter that arrangement.

- James Lindholm: **We need to really understand the distribution of the species involved relative to the distribution of the impacts** to evaluate what might result.
- Jay Johnson**: On sand waves off the East Coast, scientists have been sampling the leading edge, the top, and the back edge of the forms. Those are all critical microhabitats, and the benthic communities are totally different on all three sides.** Of interest to fisheries, **different species inhabit specific sides of the bedforms**. In San Francisco Bay, the water depth prohibited the targeted sampling of the bedform sides.
- Jay Johnson: Physical dynamics would suggest that the mining holes are going to become carbon sinks in which finer materials settle out. The communities that are going to inhabit those holes will be more diverse and in higher abundance, which could be preferable for some species of fish that would feed on those animals. Offshore, when we are looking at tracks and the fine sediments and find a hole, it's attracting fish.
- Patrick Barnard: The most heavily mined area at Point Knox Shoal is very coarse (coarse sand, a lot of gravel and a lot of rejects there too), so there's a lot of armoring of the sea bed. There are really no visible bed forms on a lot of that, probably because the sediment's so coarse but also so disrupted.
- Patrick Barnard: Bedforms in the southern part of Central Bay are quite distinct. **Where excavated, southern Central Bay bedforms have yet to reform after 10 years.**
- Jay Johnson: If you dredge just before spring recruitment, recovery is accelerated if the habitat is right (if you are in an area where the sediment composition is conducive to quick recruitment from the water column).
- Jay Johnson: **For coarse-grain sediment, recolonization is less influenced by recruitment and more influenced by immigration.**
- Aaron Carlisle: Endangered species concerns would be a focus in Suisun Bay because Suisun Bay is so close to marshlands, which are hotspots for nursery activity and a lot of important ecological processes. Stirring sediment up into the water column could potentially impact the food resources for Delta smelt or other animals of conservation concern.
- Jay Johnson: There would probably need to be a lot of sediment movement in order to affect the marshes. There was a lot of concern in the environmental impacts review about entrainment, impingement, both of larval stages as well as juveniles and adults, and because of this potential provisions were put in place and those provisions have been satisfied.
- Jay Johnson: In my personal opinion, total organic carbon is the primary indicator of benthic community composition, and grain size is secondary. In the mining areas, the Applied Marine Sciences study encountered very little organic carbon because the

physical factors wash it away. **So, in the areas where they're actively mining, my suspicion, my personal opinion, is that the physical factors are overwhelmingly controlling.**

- Jay Johnson: (On patchy distributions of species): The Applied Marine Sciences samplers encountered extremely localized, high densities of sea pens just offshore of Treasure Island (the pens were "lined up like a freeway"); this distribution pattern is unexplained.
- James Lindholm: Dungeness crab, which migrate in and out of San Francisco Bay, might experience change in habitat the same way moving fish would.
- Jay Johnson: Nobody has described or explained the Dungeness crab migration route. **Impacts of mining to the Dungeness Crab migration are unknown.**
- Jay Johnson: Migrating crabs getting trapped in mining holes is a distinct possibility, but I didn't see those kinds of holes in any of the bathymetric data and the holes start slumping pretty quickly.
- Jay Johnson: We assume that if crabs get into the holes they can get out. But there is no data to support that assumption**. So we can start putting tags on a bunch of Dungeness crab and then track them going in and out**.
- Jessie Lacy: **In particular, the coarse grain sediment benthic communities in Central Bay are fairly poorly characterized.**
- Mark Stacey: **Physical recovery would begin with bathymetric adjustment back to the natural landform. On a longer timescale, there would be an adjustment of the grain size distribution. Together, that would then define the recovery.**
- Patrick Barnard: On a fine scale, **bedforms that are wavelengths of several meters or more can probably recover extremely quickly (~hours to days) because the potential transport is much higher.**
- Patrick Barnard: Some of these **larger features in Central Bay (bed forms on the order of 80 or 100 meters long with much coarser material) would take a much longer time (months to years) to recover.**
- Scott Fenical: Areas with coarse-grain material (e.g. Point Knox Shoal) are probably not going to come back to anything they were, or at least it will take a very long time. So **recovery times are wide-ranging and really dependent on where you are and what material is on the bottom.**
- Patrick Barnard: Some bedforms – even very large one – have crests that migrate back and forth on the order of several meters during tidal cycle.
- Patrick Barnard: The net movement of the entire bedform is seaward at a rate of about two centimeters a day, even though the crest was flexing up to three meters per day.

- Patrick Barnard: Superimposed on those large forms are very small bed forms and there's probably ripples on top of those as well.
- Patrick Barnard: In Central Bay the bedforms are a little bit smaller than the bedforms at the mouth of San Francisco Bay. They're less steep, but have similar features (superimposed bed forms that are rapidly migrating on the larger forms). There are usually up to two or three different systems: large-scale, medium-scale, and a (small) scale you can't even see with the multibeam.
- Jay Johnson: **An area that undergoes successive mining events within a year will probably not recover as quickly as an area that was mined once.**
- Jay Johnson: Unknown whether the sturgeon are preying on potamocorbula and what would be the effect of removing them.
- Jay Johnson: **From an ecological standpoint, it'd be better for the miners to mine the same areas rather than spread their mining over a larger area.**
- Jay Johnson: **Ecological recovery studies indicate recovery times of 3 months to over 15 years.**
- Mark Stacey: The biological community (clams) in Suisun Bay is highly resilient.
- Mark Stacey: In Central Bay, there's a little more uncertainty as to the response of the biological community, partly because it's tied to some of the local details of the physical response and the bedform structures.
- Mark Stacey (summarizing): In Central Bay, the biological recovery will follow the physical recovery, whereas in Suisun Bay, we (unfortunately) have this very resilient ecosystem that can probably survive whatever you do it. There's a great deal of uncertainty that Patrick has illustrated in talking about the time it takes for the bedforms of various scales to reform and what that means for the microhabitats in Central Bay.
- Jay Johnson: **The benthic community of Suisun Bay and the Delta is biologically driven, whereas in Central Bay, it's physically driven.**
- Jessie Lacy: (summarizing) The spatial scale of these disturbances suggests that recolonization could occur fairly readily.
- Jessie Lacy: (summarizing) Sandy habitats are really poorly characterized as far as their populations, ecology, species richness, and spatial variability. That obviously puts everyone at a disadvantage when trying to describe how they might be affected.
- Mark Stacey: The Delta Smelt is very, very near its tipping point, and some of these mining activities are in habitats that the Delta smelt uses. The spatial scale and the persistency of turbidity plumes caused by mining may have some kind of an effect on that particular species.

- Brian Hansen (USFWS requested input from panel): **The turbidity issue is not a concern for Delta smelt.**
- Brian Hansen: A concern would be that the Delta smelt use those coarser grains for spawning. And **the Delta lease areas and Middle Ground Shoal are right around where X2 normally would be in a non-drought season.** If rougher grains are removed, you are removing spawning habitat. Slumping of this spawning habitat is a concern.
- Brian Hansen: **We need to look at whether mining activities change the bed grain size distribution on the margins.**
- Brian Hansen: **Turbidity plumes are probably not an attractant for Delta smelt.**
- Brian Hansen: Delta Smelt are prey fish so they're going to move when disturbed.

Discussion Session 4

2:45 p.m. – 3:30 p.m.

Topic: Habitat Disturbance and Recovery / Monitoring and Future Planning

- Patrick Barnard: There are certain areas of Central Bay that seem to have a much more direct connection to the Bar and to the beaches to the south and others. Certainly, Presidio Shoal seems to have a more direct connection, as opposed to Point Knox Shoal which seems to be mostly depositional.
- Patrick Barnard: **The sediment on peripheral parts of Central Bay is predominantly moving seaward, whereas in the central part of Central Bay there seems to be net movement of sediment in the landward direction. The data now support more mining in certain areas and less in others.**
- James Lindholm: **It would be interesting to do a controlled study, in which we sample the heck out of an area with all the various tools accessible, including visuals tools and possibly characterization of the fish community, and then be on board when there is extraction at that precise location.**
- James Lindholm: Rikk Kvitek was apparently doing some more mapping, so it may be possible to get better information to characterize the habitat to better understand it relative to the mining footprint.
- Aaron Carlisle: **Until we get temporal/spatial baseline data we can't really provide good recommendations.**
- Jay Johnson: **Unclear if we are destroying biological pathways (analogous to pipelines cutting off arboreal pathways). This is unlikely to be an issue in 10 years, but may be beyond that.**
- Aaron Carlisle: For monitoring, recommendation is for visual surveys (underwater video and still photography) of the Dungeness Crabs. **Despite the usual impediments to visual monitoring, it's worth thinking about and it's worth figuring out because those visual surveys would add a dimension to understanding the system that's currently not present.**
- James Lindholm: **Monitoring will require dragging nets through some of these habitats and getting the fish and finding out what they're actually eating.**
- Francis Parchaso: A simple experiment would be going into an area, characterizing it, mining it, and returning to it for monitoring.
- Patrick Barnard: **We put our heads together for years to figure out how the instrument the bed at the Golden Gate, and it's probably never going to happen; it's just too dynamic.**
- Patrick Barnard: **We'd love to stick a tripod on the bed at the Golden Gate to take measurements, since there's no measurement of transport along the bed.**

- Scott Fenical: Monitoring and publishing multibeam surveys has been useful, but even a bunch of single beam data at times are helpful and more economical.
- Patrick Barnard: **Portland USACE has put (luminescent?) tracers out to track the sediment movement off the mouth of the Columbia River to the south. We could start with a small tracer study.**
- Patrick Barnard: We now have nice grain-size distribution maps.
- Patrick Barnard: We haven't done a whole lot of modeling recently in terms of specifically looking at the mining impacts, but obviously Scott Fenical has shared some of that data, so **we could definitely fine-tune what's happened in the bottom boundary layer[1].** Of course, even knowing all that, there's still obviously a great uncertainty in calculating sediment transport rates, but it's getting closer to where we want to be.
- Francis Parchaso: The life histories of crab and fish are pretty well understood. We know the broad seasonality of fish and crab lifestages and we know the areas being mined and/or utilized by those various lifestages. **We just need to be careful and aware that we could be influencing these animals during a certain time of year.**
- Francis Parchaso: **We don't know where crabs are marching through Central Bay but we do know during certain months they're in a certain area. Same with the salmon.**
- Francis Parchaso: **To answer the questions regarding recovery of the benthos, we have to have the technology to go down to the mining sites and then go back and watch them.**
- Francis Parchaso: We tried to put tripods in with cameras but it's so turbid sometimes you just get a grey picture.
- Jessie Lacy: Our team is using timed still-photography in the Strait of Juan de Fuca. The cameras have gotten better, the resolution has gotten better, but it's certainly really difficult technology to use in the Bay due to the turbidity.
- Francis Parchaso: We **could use infrared photography or do high frequency scanning**, but that's technology that we don't have yet and it's technology I don't think anyone is going to look into yet.
- Francis Parchaso: There's a seabed AUV (Autonomous Underwater Vehicle[2]). It has a sonar that's going to take still photos.
- Jay Johnson: **About two years ago I cut out an article in the newspaper about NOAA planning to deploy an ROV (Remotely Operated Vehicle[3]) somewhere in west Central Bay to take video. It might be worth looking into and trying to find out what they got.**

[1] A bottom boundary layer (BBL) is a uniform layer at the seafloor interface that is well-mixed (non-stratified). Sand transport would predominantly take place within the BBL.
[2] AUVs are completely autonomous (unmanned) and typically torpedo-shaped) Unlike gliders, AUVs are typically motorized.
[3] ROVs are actively driven by a person, usually according to a video feed. Large ROVs are often connected by cable to a ship.

- Patrick Barnard: The Richmond-San Rafael Bridge could also be instrumented. The problem with the Richmond-San Rafael Bridge is that there are no bedforms there; it's got plain beds, but we could instrument it a bit and we could look at it. A mile-long scour cast in the lee of the bridge is an interesting feature and an indicator of transport direction. Same with the Carquinez Strait.
- Patrick Barnard: **Any direct measurements of bed load transport would be a benefit to the modeling and its extrapolation to a broader area.**
- Jessie Lacy (to Mike Bishop): The leases are actually bigger than area that you really could use? (Mike Bishop: Yep, you know, 7779 north which is in Raccoon Strait, as far as I know we've never mined up there and it -- I don't know why we have a lease; there that was clearly before we were there, before I was [around]).
- Scott Fenical: **The further you take a channel out of the equilibrium that it was in (by mining successively), the longer it will take the channel to recover. And if you take enough of material out, a channel is not going to be able to return to what it was.**
- Scott Fenical: **We're seeing deepening of the Suisun Bay channels where the channels are being mined quite a bit and where there is not much coarse sediment transport.**
- Jessie Lacy (summarizing): **Managing the mining with spatial focusing might be a candidate strategy, both in terms of: (1) where the direction of transport is into the bay versus out of the bay, and (2) the ecological benefit of constraining impacts to specific areas.** For the spatial focusing, it needs to be put in the context of recognizing the scale of the mining footprint relative to the scale of the available habitat, for instance, in a particular range of grain size.
- Jessie Lacy (summarizing): For temporal considerations, until we have better information on the biological usage, the types of species using the habitat, and the life stages that are important, we just don't have the information to recommend a good strategy. For the crabs, it might be an essential strategy, but there's no recommendations that really could be made now. **Getting the information to be able to make a temporal recommendation actually could be very sensible from an ecological point of view.**

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Post-panel survey

For the panelists: Many research needs and potential research methods were identified at the sand mining science panel meeting, in addition to specific recommendations for management. So that we may best incorporate these recommendations into our project analyses, please review the following for accuracy, editing where necessary and contributing as requested.

Please edit or annotate, then **rank** the following **research needs/recommendations** according to their priority to assist us in better understanding potential impact from sand mining:

- ☐ Monitor changes in depth and turbidity during sand mining events.
- ☐ Determine how much of the total sediment flux out of the Delta is sand, and whether the estimate of 10% is still valid.
- ☐ Design and support research efforts to estimate the flux of sediment out of the Golden Gate.
- ☐ Describe the recovery (or non-recovery) of historic borrow pit sites.
- ☐ Develop a body of comparative data on infaunal communities in sandy areas.
- ☐ Describe the epifaunal communities in sandy areas.
- ☐ Describe the Dungeness crab migration route.
- ☐ Describe how internal wave structure influences the dispersal and settlement of recruits.
- ☐ Estimate bedform recovery times in San Francisco Bay
- ☐ Develop a monitoring plan to identify impact thresholds and threshold effects.
- ☐ Collect good baseline data on the use of the habitat by different species.
- ☐ Identify the scale of the spatial footprint of mining events in relation to the available habitat area.
- ☐ Transport mechanisms have not yet been quantified and this represents a key uncertainty. For example, the relative importance of tidal currents versus fresh water flows is still unknown.

Please edit or annotate, then **rank** the following **proposed methods** according to their **feasibility** *(exclusive of cost)*:

- ☐ Directly measure bedform transport to improve modeling. (Patrick Barnard)
- ☐ Intensive sampling of infaunal and epifaunal communities. (panel)

- ☐ Crab tagging, to describe the Dungeness migration and assess impacts (Jay Johnson)
- ☐ Visual surveys (video + still photography), fish surveys, and trawls to see what fish are eating. (Aaron Carlisle; Francis Parchaso mentions the futility of tripod timed photography;)
- ☐ Infra-red photography. (Francis Parchaso)
- ☐ Use ROV excursions to characterize the three sides of the San Francisco Bay bedforms (Jay Johnson)
- ☐ Seabed AUV deployable off of a small boat, now housed at WHOI. (Francis Parchaso)
- ☐ Investigation of a possible ROV deployment 2 years ago (NOAA/NMFS?) that is believed to have taken some video/photos in Central Bay. (Jay Johnson)
- ☐ Investigations needed pre-, during, and post-mining events to better understand mining impacts (ideal way to study the direct impacts of mining on benthic communities and the physical environment). (panel)
- ☐ Use sidescan sonar to see if there is a difference between the size or structure of the bedforms in the active mining area and in the non-mined areas. If there is a difference, that difference can be used to infer quantitative and qualitative changes in transport. (Mark Stacey)
- ☐ Analysis of historic borrow pit bathymetry and evaluation of their recovery. (Patrick Barnard)
- ☐ Conduct a pilot tracer study (similar to what Portland USACE has done to track the movement of dredge material at the mouth of the Columbia River) to track sediment transport along bedforms and out of the Gate. (Patrick Barnard)

Please add specific **management recommendations** that you feel can and should be immediately applied in our analysis of the proposed sand mining projects, and in our evaluation of the sand mining permit applications for Commission approval.

- Focus on the relative disruption in flux/rates of transport as a result of sand removal, rather than focus only on volume. (Mark Stacey)
- Compare sediment transport rates/fluxes with mining activity to inform management decisions. (Mark Stacey)